

Monitoring Bloom Dynamics of a Common Coastal Bioluminescent Ctenophore

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LONG-TERM GOALS

The long-term objective is to develop predictive models of bioluminescence potential in the coastal zone environment.

OBJECTIVES

As naval operations move into coastal waters, the possible impact of sporadic blooms of bioluminescent organisms on clandestine operations is of increasing concern. One such bloom-forming light producer is the ctenophore *Mnemiopsis leidyi*. This native-American comb jelly was first introduced into the Black Sea in 1982 where it caused the total collapse of the local fisheries. It has recently broken out into the Mediterranean Sea and there is concern that it may continue to spread. Also, there is evidence that blooms within its native range are increasing and producing profound impacts on coastal ecosystems.

Although the causes of jellyfish blooms are not well understood, correlations have been made between changes in jellyfish density and changes in physical factors, such as temperature and salinity, and biological factors, such as prey abundance and predation (Graham et al., 2001, Kremer, 1994). Developing a meaningful predictive model with these multiple variables depends on a large sample size. Current sampling methods for jellyfish populations are done with net collections by hand at stations weekly, monthly, or seasonally. These time scales severely limit our knowledge of changes in *Mnemiopsis* sp. abundance. Bloom events may not coincide with sample collection days, but during the gaps between samples, limiting the utility of data and its relation to physical and biological variables. Our objective is to greatly reduce sampling intervals and greatly expand the spatial coverage of data collected by removing the requirement for hand sampling and automating all aspects of the data collection process.

APPROACH

With support from the Office of Naval Research, we have been developing a new kind of wireless, coastal monitoring system that is integrated at the component level in order to radically reduce costs and complexity. Each sensor string or Kilroy measures conductivity, pressure, speed-of-sound along several paths, optical backscatter, and two components of magnetic flux (Figure 1). From these basic measurements, salinity, flow speed and direction, package depth, tidal parameters, wave characteristics, and package orientation are calculated. Also, each Kilroy is fitted with a low-cost bathyphotometer (BP), specifically designed for coastal monitoring (Figure 2). The geometry and sampling characteristics of the BP internal solid-state sensor array are based on findings with the

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HIDEX Bathyphotometer (Widder et al., 1993, 2003, 2005) and the data handling will incorporate recently developed classification and concentration measurement algorithms (Davis et al., 2005). Kilroy also integrates a GPS unit, communicates with up to 255 other systems via a multi-drop RS-485 connection, logs data in a PC-readable format to Secure Digital/MultiMediaCards, and is powered from either a single, internal, rechargeable Lithium Polymer battery or from an external unregulated supply – either solar or wave generator (Figure 3). Data is available via the Internet and is presented using transparent Adobe Flash layers overlaid on Google Maps (Figure 4). A network of 7 Kilroy sensor pods is currently installed in the Indian River Lagoon on the east coast of Florida and reporting data in realtime to a web interface. This network is scheduled to be expanded to 25 pods by the end of October 2008.

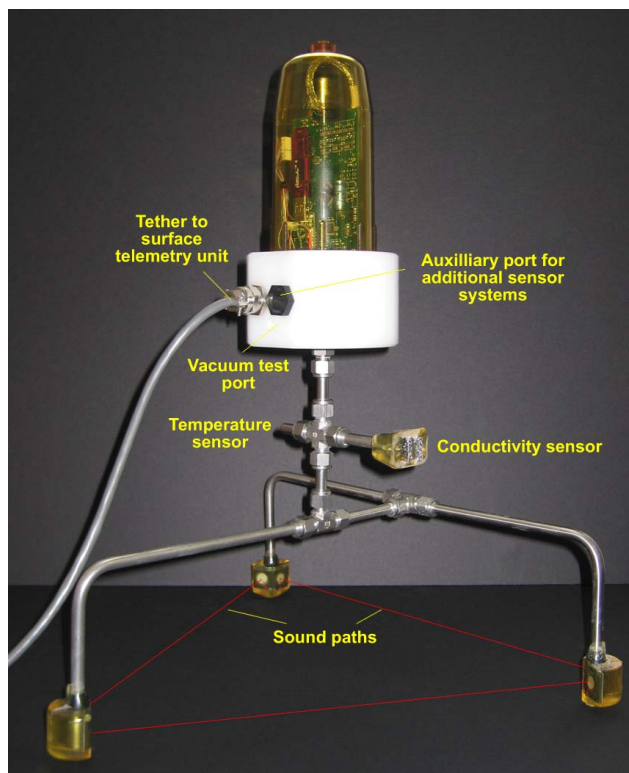


Figure 1: Photograph of the Kilroy sensor suite for coastal monitoring. Electronic circuitry is housed in an off-the-shelf pool filter housing good to a depth of 10 m. The cable exiting from the base of the housing is a tether to the surface, which connects to Kilroy’s Voice telemetry system.

The auxillary port, also on the base of the housing, connects to additional sensors such as the bathyphotometer, the turbidity sensor or another Kilroy sensor suite. Sensors can be connected together as a sensor string. Branching out at right angles from the pressure tubing exiting from the base of the housing are the temperature sensor and conductivity sensor. Beneath these a triangular array of acoustic transmitters and receivers measure speed of sound, flow speed and flow direction.

The Kilroy network provides a new approach to monitoring bloom dynamics, without being constrained by routine dependence on net collections, which are labor intensive, patchy and infrequent and, instead permits the collection of both biotic and abiotic data continuously. Our approach is to correlate *M. leidy* abundance data provided by the bathyphotometer with Kilroy-measured environmental variables, quantify the impact of *M. leidy* blooms on the abundance of local primary and secondary producers, measure feeding, growth, and reproduction rates of *M. leidy* in controlled

laboratory studies to test hypotheses of control factors derived from multivariate correlation analyses and develop a likelihood of occurrence model based on a recently developed ecological forecasting system for the sea nettle, *Chrysaora quinquecirrha* (Decker et al., 2007). Specifically, we will use multivariate regression techniques to develop habitat (i.e., environmental conditions) models for understanding and predicting variations in abundance of *M. leidyi*.

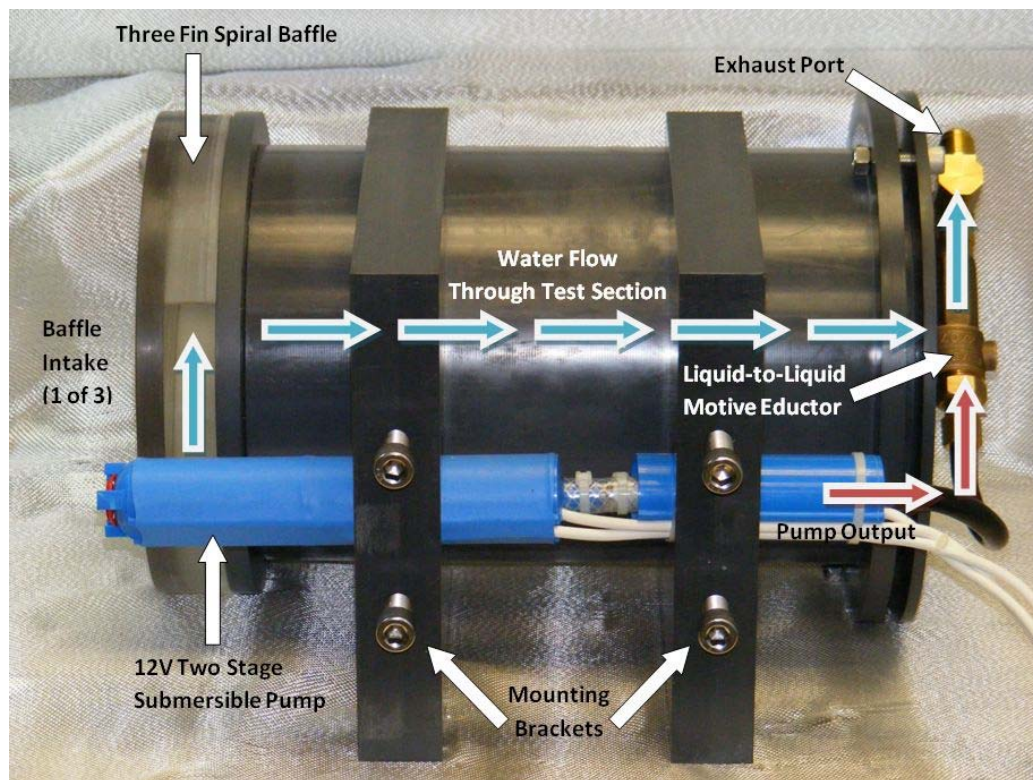


Figure 2: Photograph of the Kilroy Bathyphotometer with arrows indicating the direction of water flow through the light-baffled intake on the left into the detection chamber test section. The two stage submersible pump pulls in water at the end of the first stage, pumps to the second smaller stage, and then outputs (red arrows) to the Liquid to Liquid Motive Eductor. The eductor is the key component for moving water samples through the system. As the pump forces high pressure water through the eductor and out the exhaust port, suction is created at the point where the eductor is connected to the main body of the bathyphotometer. This suction causes water to be pulled into the Baffle Intake (there are 3 evenly spaced baffle intakes, 120 degrees apart, one is visible), up through the test section (blue arrows) and into the eductor where it mixes with the pump water and leaves through the exhaust port. The point of the design is to create passive suction to draw samples into the test section, which prevents the pump from being fouled and organisms such as *Mnemiopsis leidyi* from being destroyed by the impellers.

WORK COMPLETED

For the last two years, the food source for *Mnemiopsis* sp., mesozooplankton, has been monitored on a weekly basis in the Indian River Lagoon. Monitoring *Mnemiopsis* sp., along with mesozooplankton, provides information on which changes in mesozooplankton may trigger *Mnemiopsis* sp. blooms, how the mesozooplankton community is altered after a *Mnemiopsis* sp. bloom, and seasonal cycles in

mesozooplankton in the Indian River Lagoon. Mesozooplankton samples were collected on incoming and outgoing tides and filtered to analyze the mesozooplankton in the size range 100 to 850 μm . These samples were run through an imaging flow cytometer and images were classified into groups to genera. Mesozooplankton samples have been collected from September 2006 to September 2008, with a break in sampling from May to July 2008 for equipment repairs. These data provide comparisons of seasonal differences, and differences in the mesozooplankton assemblage on the incoming and outgoing tide.



Figure 3: Photograph of a typical remote Kilroy system installation showing the Kilroy sensor suite attached to a dock piling underwater (as inset), cabled to Kilroy's Voice telemetry/ power box above-water and a 10W solar panel (at the top of the piling), which keeps the reserve battery charged.

To determine potential locations for the Kilroys with bathyphotometers, plankton net tows were conducted at three stations throughout the Indian River Lagoon. Although these collections could not provide *Mnemiopsis* sp. bloom densities, thus emphasizing the need for the Kilroy bathyphotometer to more accurately measure these populations, the plankton net tows did provide data on the presence of

Mnemiopsis sp. from week to week. In the future, these trends will be compared to the constant data stream from the Kilroys, which will again highlight the need for this improved method. Plankton net tows were conducted weekly at each of three locations: Barber Bridge in Vero Beach (27°39'11.51"N 80°22'14.99"W) (from May 2008 until present), the Dockside Inn in Fort Pierce (27°28'00.71"N 80°18'07.43"W) (from September 2006 until present), and the Roosevelt Bridge in Stuart, FL (27°12'09.27"N 80°15'28.54"W) (from September 2007 until May 2008).

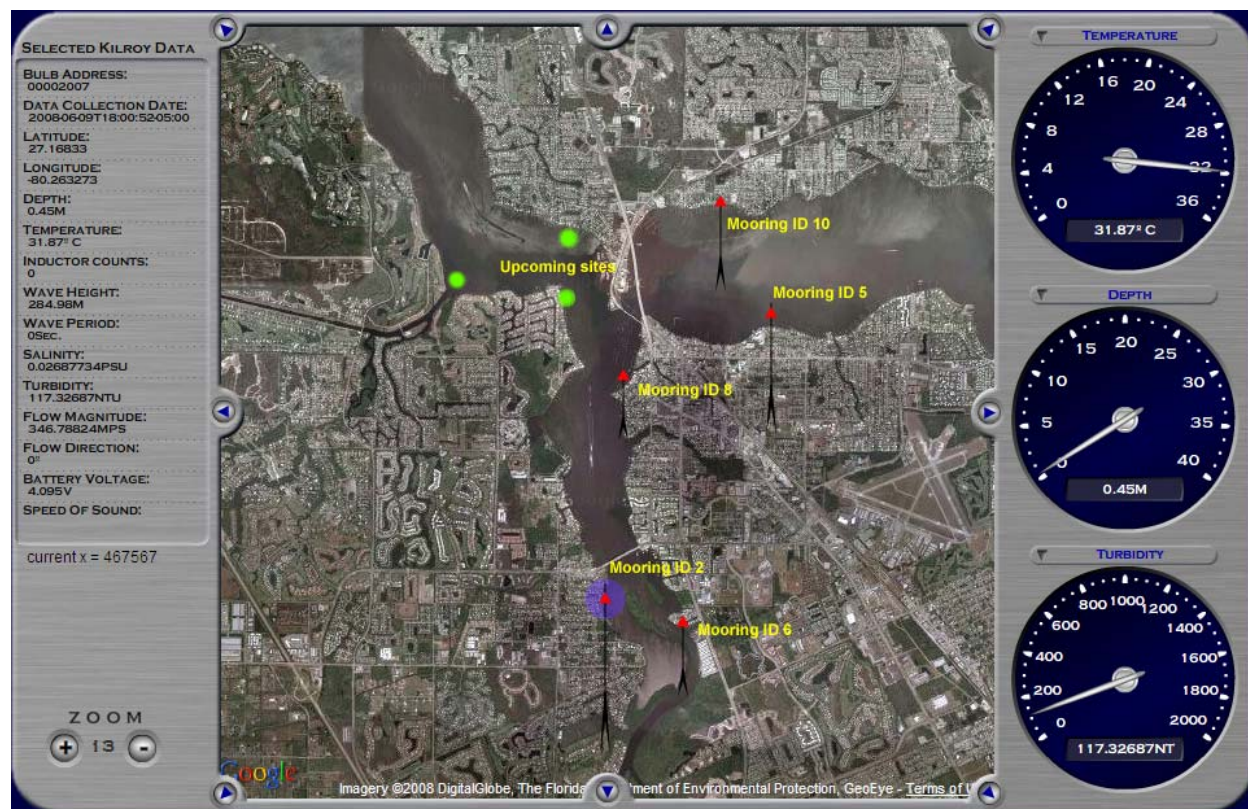


Figure 4: Wireless network data screen showing Google Map satellite view of the St. Lucie Estuary, which is part of the Indian River Lagoon, Florida. Icons representing 5 Kilroy installations are displayed as arrows overlaid on the satellite image. Currently all arrows point North because the speed of sound algorithm is applied in post-processing. In the next version of the software the algorithm will be run in real-time and arrows will point in the direction of most recently measured flow and arrow length will be proportional to flow speed. Clicking on an icon displays data on the left-hand side of the screen, shown as data collection date, latitude, longitude, depth, temperature, inductor counts, wave height, wave period, salinity, turbidity, flow magnitude, flow direction, battery voltage, speed of sound and soon-to-be-added, bioluminescence. Three gauges on the right-hand side of the screen display user-selected variables that change value as the mouse is moved from one icon to the next. Variables shown are temperature, depth and turbidity. Three green dots located in the North fork of the St. Lucie River indicate sites of future Kilroy installations.

Seven Kilroys have been deployed as a network in the Indian River Lagoon and are synchronously logging and reporting measurements every 30 minutes over the GSM cellular data network (GPRS) via the Kilroy's Voice telemetry system. Tank tests to calibrate the bathyphotometers are scheduled to be completed by the end of 2008.

RESULTS

Large variations in mesozooplankton abundance throughout both years were documented (Figure 5). In 2007, the greatest abundance of mesozooplankton occurred from January to April. In 2008, a longer period of high abundance of mesozooplankton was observed, with peaks of abundance occurring during October, December, April, and September. The predominate zooplankter in the samples was the copepod, *Acartia* sp., a known prey item for *Mnemiopsis* sp. Attempts to correlate variations in mesozooplankton abundance with *Mnemiopsis* sp. abundance were unsuccessful, primarily due to the extreme patchiness of the ctenophore distribution, which supported our hypothesis that in order to conduct statistically significant correlation analyses, we need to be monitoring blooms on much shorter space and time scales than is possible with standard field sampling methods.

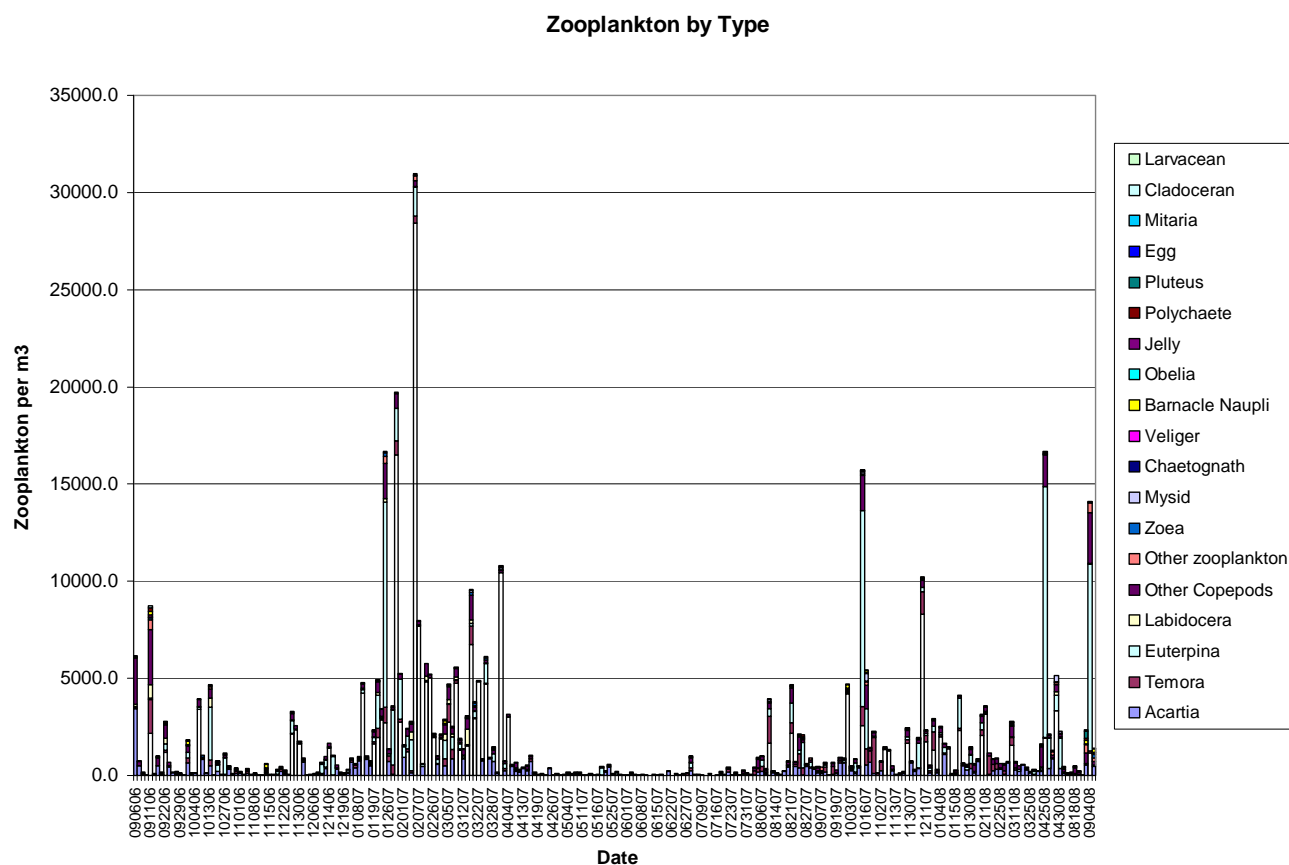


Figure 5: Mesozooplankton collected from the Indian River Lagoon and categorized by type over a two year period from September 6, 2006 to September 4, 2008. Data from May to July of 2008 is not included due to equipment malfunction and repair during that time period. The bar graph plots zooplankton per cubic meter and shows a preponderance of the copepod, *Acartia*, throughout the sampling period. The greatest abundance in 2007 was between January and April with peak abundance exceeding 30,000 per cubic meter in February 2007. In 2008, peaks of abundance were observed during October, December, April, and September.

Variations were also documented in the presence of *Mnemiopsis* sp. at the three locations in the Indian River Lagoon. *Mnemiopsis* sp. were most abundant at the Roosevelt Bridge, Stuart location. Although no comb jellies were found in September and October 2007, from November 2007 to May 2008,

Mnemiopsis sp. were present at every collection, sometimes numbering in the hundreds of jellies in one net sample. At the Barber Bridge, Vero Beach, *Mnemiopsis* sp. were collected in May and September 2008, but absent during June, July, and August 2008. At the Dockside Inn, Fort Pierce site, the presence of the comb jellies varied from month to month. *Mnemiopsis* sp. were found in the net during September 2006, October 2006, November 2006, January 2007, March 2007, April 2007, July 2007, September 2007, December 2007, January 2008, February 2008, March 2008, and September 2008. *Mnemiopsis* sp. were absent from collections during the months of December 2006, March 2007, June 2007, October 2007, November 2007, April 2008, and August 2008.

IMPACT/APPLICATIONS

As incidents of jellyfish blooms, especially *Mnemiopsis leidyi*, continue to increase and develop more rapidly, the need to monitor changes in jellyfish populations and predict bloom events becomes more important. Blooms of *Mnemiopsis leidyi* can have great impacts on the ecosystem and fisheries as a voracious mesozooplankton predator, and on clandestine military operations as a mechanically stimulated bioluminescent emitter. Thus, there is a great need to develop a bioluminescent jellyfish monitoring and forecasting system for both naval planners and policy makers seeking proactive means to respond to the ecosystem imbalance that such blooms may represent.

RELATED PROJECTS

Development of a large scale wireless bioluminescence sensor array, which is the basis for the high-resolution data collection and proposed correlation analysis, is being funded under Office of Naval Research grant N00014-06-1-0153, entitled Bioluminescence Truth Data Measurement and Signature Detection.

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